

# TECHNICAL NOTE

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EXPERIMENTAL INVESTIGATION OF LITHIUM HYDRIDE  
AS A HEAT-SINK MATERIAL

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## SUMMARY

An experimental investigation using relatively small laboratory-type test containers was made in order to obtain some insight into the possibility of using lithium hydride for cooling applications where high heat loads are encountered.

When lithium hydride was heated from room temperature to 1880° F at ground level atmospheric pressure, the material absorbed about 6000 Btu per pound, which indicated that about 75 percent of the lithium hydride was dissociated. The cooling characteristics of dissociating lithium hydride were therefore evaluated with two types of instrumented stainless-steel containers that could be electrically resistance heated. Both types were closed at one end. One type container was a 1/2-inch-diameter tube, 10 inches long; the other type was  $1\frac{1}{2}$  inches square and 3 inches high.

From heating runs made with the  $1\frac{1}{2}$ -inch-square containers at heat fluxes of the order of 30 to 40 Btu per second per square foot, it was found that dissociating lithium hydride probably can be used as an effective heat sink provided that certain undesirable cooling characteristics can be tolerated. The container must be so designed that there is a large ratio of free surface area to volume for the lithium hydride, and the hydrogen vent system must confine the coolant to the container during the dissociation period. During dissociation the cooling characteristics are likely to be erratic and unpredictable, and relatively large temperature gradients may occur in the container wall. Some of these unfavorable cooling characteristics can be reduced by the addition of about 13 percent pure lithium to the lithium hydride charge.

The large amounts of hydrogen gas liberated during dissociation made it impractical to use lithium hydride as a high-capacity heat sink in containers having a diameter of 1/2 inch and a heat input of 10 Btu per second per square foot. In containers with such small diameters the liberated gas expelled the lithium hydride from the container before a practical amount of dissociation had occurred.

## INTRODUCTION

Because of its high heat of dissociation per unit of weight and the temperature at which dissociation starts, lithium hydride appears to be a desirable heat-sink material for cooling applications such as those encountered in hypersonic airplanes, space planes, reentry vehicles, and solid-propellant rocket engines if its heat-absorption capacity can be used effectively. An experimental investigation was therefore made with laboratory-type equipment to determine the feasibility and effectiveness of utilizing lithium hydride as a heat sink in applications for temperatures up to the order of  $2000^{\circ}$  F and heat fluxes up to 30 or 40 Btu per second per square foot.

It can be shown that when the specific heat and heat of fusion of lithium hydride are considered, the material can absorb about 3260 Btu per pound when it is heated from  $77^{\circ}$  F to about  $1500^{\circ}$  F. If the material could also be dissociated, an additional amount of heat of the order of 4500 Btu per pound could be absorbed. For the temperature range considered, lithium hydride would then be capable of absorbing more heat per unit of weight than any other material known to the authors. Reference 1 shows that dissociation of lithium hydride starts at about  $1500^{\circ}$  F at 1 atmosphere of pressure and that only a small portion of the lithium hydride will dissociate at this temperature unless the pressure is reduced. For the most effective use of lithium hydride as a heat sink, it should be utilized at temperatures and pressures that permit a considerable portion of the material to dissociate. From data that are presented in reference 1 it is indicated that even at a pressure of 200 millimeters of mercury only about 80 percent of the lithium hydride would dissociate at a temperature of  $1517^{\circ}$  F. In order to dissociate more than about 92 percent of the lithium hydride at this temperature, a pressure of less than 8 millimeters of mercury would be required. No information appears to be in the literature concerning the amount of dissociation that occurs at higher temperatures.

The high-temperature components of hypersonic airplanes, space planes, reentry vehicles, or solid-propellant rocket engines could possibly be fabricated from alloys that have reasonable strength and durability at temperatures as high as  $1800^{\circ}$  to  $2000^{\circ}$  F. Reference 2 shows that when the leading-edge regions of a typical hypersonic airplane were cooled to  $1800^{\circ}$  F, the associated heat fluxes ranged from 15 to 95 Btu per second per square foot. It was also suggested in reference 2 that lithium hydride might be a possible coolant for the leading-edge portions of the airplane.

The present investigation was made, therefore, to determine whether a significant portion of the potential heat-sink capacity of lithium hydride can be realized at temperatures several hundred degrees higher than 1517° F (the temperature at which dissociation starts at 1 atm of pressure). It was also desired to obtain some general idea of the cooling characteristics of dissociating lithium hydride for temperatures up to about 2200° F.

The heat-sink capacity of lithium hydride was evaluated in a calorimeter at a pressure of about 1 atmosphere and a temperature of 1880° F for a heat flux into the lithium hydride of 13 Btu per second per square foot. The general cooling characteristics of dissociating lithium hydride were evaluated in two types of electrically heated containers, one with a low and one with a high ratio of free surface area to volume for the liquid lithium hydride. The heat flux into the coolant was 10 to 40 Btu per second per square foot, and the maximum container wall temperature was about 2200° F.

#### APPARATUS

The effectiveness of the lithium hydride cooling process for ambient ground-level atmospheric pressure was established in a calorimeter such as that shown in figure 1. It consisted of an electrically heated crucible that contained barium chloride salt (melting point, 1765° F). A  $2\frac{1}{2}$ -inch-diameter stainless-steel lithium hydride container was suspended in the salt. Thermocouples were placed in the salt bath so that its temperature could be monitored. The voltage to the heating element was adjustable, and the power input was recorded on a strip-recording wattmeter.

The cooling characteristics of dissociating lithium hydride were investigated in two types of containers, one with a relatively low total volume and a low ratio of liquid lithium hydride free surface area to volume and the other with a relatively large volume and a large ratio of liquid lithium hydride free surface area to volume.

The small-volume container was made from 1/2-inch-diameter type 302 stainless-steel tubing with a wall thickness of 0.031 inch. The lower end of the tube shown mounted in the test apparatus in figure 2 was sealed, and the upper end was fitted with a 1/4-inch tube to vent the hydrogen gas evolved during dissociation. The 1/2-inch-diameter tube was used because it approximates the leading-edge size of the wing of a hypersonic airplane or the tube size that might be used in a conventional heat exchanger. During the experiments the tube-type lithium hydride containers were placed within an insulated box as shown in figure 2.

The large-volume containers were square in cross section (fig. 3). The containers were made from 0.031-inch-thick type 314 stainless steel. The bottom extended 1/2 inch on opposite sides of the container to permit the connection of electrical leads for heating purposes. This container was insulated and mounted for test purposes as shown in figure 3(b). In some of the tests a cover with a 3/8-inch-diameter vent tube was welded on the top of an open container as indicated by the dashed lines in figure 3(b).

Chromel-Alumel thermocouples were spot-welded to the walls of the test containers so that their temperatures could be monitored continuously. Seven thermocouples were placed on the tube-type containers (fig. 2); five thermocouples were placed on the bottom of the square-type containers (fig. 3(c)).

#### PROCEDURE

Throughout this investigation lithium hydride powder or compacted lithium hydride powder was used. In all cases the powder was commercially available Class V powder (guaranteed assay is 93 percent and all particles pass through 35 mesh screen).

The cooling effectiveness of lithium hydride was evaluated in the calorimeter described previously. The procedure was first to bring the calorimeter to a thermal equilibrium condition with the lithium hydride container empty and the salt bath at a temperature of about 1880° F (this was near the maximum temperature capabilities of the calorimeter). At this equilibrium condition the heat (or power) input, as indicated by the recording wattmeter, was constant with time. Lithium hydride charges that consisted of compacted cylinders of lithium hydride powder were then dropped into the container through the vent tube (fig. 1). These cylinders were about 1/2 inch in diameter and weighed about 5 or 6 grams. Only one cylinder was used for a given test run. When the lithium hydride was placed in the container, the temperature of the salt bath was maintained at a constant value by increasing the power input to the crucible. The test was continued until the power input level returned to the level that existed for the equilibrium condition prior to the introduction of lithium hydride into the system. The amount of heat absorbed by the lithium hydride was assumed equal to the additional electric power required to maintain a constant salt bath temperature. Calibration tests of the calorimeter indicated that the maximum heat flux into the lithium hydride container was about 13 Btu per second per square foot.

The effectiveness of the lithium hydride cooling process was assumed to be equal to the heat absorbed by the lithium hydride divided by the theoretical amount of heat that would be absorbed by a completely dissociated lithium hydride charge when heated from room temperature to the

temperature of the salt bath (1880° F). A sample calculation for determining the amount of heat that can be absorbed by lithium hydride when it is heated from room temperature to 2000° F and assumed to be completely dissociated is presented in the appendix.

The cooling characteristics of dissociating lithium hydride were determined in both the tube- and square-type containers. Each test container was charged with 15 grams of lithium hydride powder within a dry-box. For the tube-type container, the 15-gram charge filled the tube to a depth of about 10 inches. For the square-type containers, the depth of charge was about 3/4 inch as indicated in figure 3(b).

In order to prevent contamination of the lithium hydride charge from air or moisture while the container was being transported and installed in the test equipment, the tops of the containers were sealed while the containers were still in the drybox. For the tube- and square-type containers with a cover and vent tube assembly, a cork was placed in the end of the vent tube. For the square-type containers with an open top, a plastic film cover was placed over the end of the container.

The cork plugs on the tube-type containers were loosened immediately prior to the start of a test and were permitted to remain loosely on the top of the vent tube until evolution of hydrogen during the dissociation process forced the cork from the vent tube. For the square-type containers with a cover and vent tube assembly, the vent tube was bent into an inverted U-shape with the cork in place. Immediately prior to testing, the end of the vent tube was submerged in kerosene and the cork was removed. For containers with plastic covers, the covers were permitted to remain in place until they were burned off after the heating cycle for a given container was started.

For each type of container configuration investigated, a given container was charged only once with lithium hydride and heated. This procedure was followed in order to avoid the use of containers that might have become corroded or otherwise damaged during a previous run and thus would affect subsequent cooling results.

The initial experiments consisted of (1) heating empty containers at a given electric input and obtaining the time-temperature relation for the containers, (2) charging the containers with lithium hydride, and (3) repeating the heating cycle with the same electric input that was originally used for heating the empty container. The time-temperature relations of the charged containers were then compared with those of the empty containers, and the cooling performance of the lithium hydride was evaluated by observing the differences between the time-temperature curves of the empty and the charged containers.

In some instances pure lithium was added to the lithium hydride in order to determine whether such an additive would improve the heat-transfer characteristics of the lithium hydride.

## RESULTS AND DISCUSSION

### Cooling Effectiveness

The cooling effectiveness of lithium hydride when heated from room temperature to 1880° F at constant ground level pressure was obtained by the method outlined in the PROCEDURE. Calibration tests indicated that the maximum net heat flux into the lithium hydride was about 13 Btu per second per square foot.

A total of six separate runs was made to determine the overall effectiveness of the cooling process. Effectiveness values (the ratio of the actual heat absorbed by the lithium hydride to that of the ideal amount of heat that would have been absorbed between 80° and 1880° F if 100 percent dissociation had occurred) ranged from 0.70 to 0.97; the average value of effectiveness for the six runs was 0.83. This average indicates that complete dissociation did not result for the conditions of the tests. If the lithium hydride is assumed to have melted completely and the heat absorption values given in the appendix are used, the inference may be made from the results that at 1880° F only about 75 percent of the lithium hydride was dissociated in the experiments. The effectiveness value of 0.83 represents a total heat-sink capacity equivalent to about 6000 Btu per pound, which is a substantial heat capacity compared with other possible heat-sink materials. Even though complete or nearly complete dissociation was not achieved, the indication of favorable overall cooling effectiveness warranted investigation of the cooling characteristics of dissociating lithium hydride.

### Cooling Characteristics of Dissociating Lithium Hydride

Tube-type container. - Two test runs were made with charged 1/2-inch-diameter tube-type containers following the procedure discussed previously. Calibration tests indicated that the heat flux into the lithium hydride was about 10 Btu per second per square foot. For both runs the time-temperature data obtained were very erratic for all thermocouple locations. In general, it appeared that the lithium hydride was not cooling the container to any significant degree. During the runs considerable quantities of molten material were ejected from the vent tube. After the containers had cooled at the conclusion of the tests, they were examined to determine their internal condition. Practically all the material originally in the containers was gone. The fact that the containers were essentially empty, in addition to the very poor cooling results, seemed to indicate that as



the lithium hydride reached the temperature at which dissociation starts (about 1500° F) the liberation of hydrogen gas was so great that it severely agitated the molten contents within the container. As the gaseous hydrogen passed upward through the container and out the vent tube, large amounts of molten lithium hydride were carried along and expelled from the container. In this manner most of the lithium hydride coolant was ejected from the container before complete dissociation took place.

It was concluded from these results that dissociating lithium hydride would not function suitably as a coolant in a 1/2-inch-diameter tube where the heat input into the lithium hydride was of the order of 10 Btu per second per square foot.

Square-type container. - Because of the difficulty encountered in attempting to employ dissociating lithium hydride as a coolant in a relatively small diameter and small volume tube, it was thought that a container having a larger volume and cross-sectional area than the tube-type container might permit the lithium hydride to cool more effectively. A container  $1\frac{1}{2}$  inches square and 3 inches high, as described previously, was therefore arbitrarily selected. Such a container has relatively large cross-sectional area ( $2\frac{1}{4}$  sq in.) compared with that of the tube-type container (0.196 sq in.). Also, the volume of the square-type container was 3.5 times that of the tube-type container. The larger cross-sectional area and volume of the square-type container were expected to result in entrapping a smaller quantity of lithium hydride in the liberated hydrogen and carrying it out of the container.

The square-type container does not represent a known type of direct application for a cooling device. The general principle, however, could possibly be used in some dual coolant system where a high-temperature cooling fluid would transfer its heat to the lithium hydride in a suitable heat exchanger.

For all the tests made with square-type containers, the electric power input to the container was maintained at a constant value of 2000 watts. Calibration tests indicated that this power input resulted in a net heat input to the lithium hydride of the order of 30 to 40 Btu per second per square foot.

The square-type container was first investigated with an open top as illustrated in figure 3(a). The initial charges placed in the container consisted of 15 grams of lithium hydride powder. Three separate runs were made (fig. 4). The boundaries of the dark areas shown in figure 4 represent the minimum and maximum temperatures as indicated by the five thermocouples on the bottom of the container. For comparison, the results of heating an empty square-type container are shown in figure

4(a) by the light area bounded by curves that indicate the minimum and maximum temperatures measured on the bottom of the empty container.

During the runs with the open-top containers it was observed that after about 5 minutes of heating, violent agitation of the fluid within the containers would occur and much of the coolant would be ejected from the container. As the hot fluid was ejected, it would severely attack the insulation on the containers; furthermore, a hydrogen fire would generally start. This behavior would, of course, affect the heat-transfer characteristics and the temperatures of the containers. The significance of the data in figure 4 after 5 minutes of operation is therefore questionable. Because of the difficulties, the open-top-container tests were terminated after 6 or 7 minutes of operation.

In spite of the ejection of coolant from the open-top containers, it is believed that the temperature data of figure 4 are of some general use and that several conclusions can be made. Comparison of the temperatures of the charged containers with those of the empty container indicates that the lithium hydride is absorbing heat and contributing to the cooling of the containers. For example, after  $3\frac{1}{2}$  minutes of operation the empty container reaches temperatures of the order of  $2400^{\circ}\text{F}$ , while the charged containers reach a maximum temperature range from about  $1480^{\circ}\text{F}$  (run 2) to  $1730^{\circ}\text{F}$  (run 3). For run 3, however, a maximum temperature of  $2000^{\circ}\text{F}$  was reached after  $2\frac{1}{4}$  minutes of heating, followed by a decrease, and then a leveling off of the maximum temperature for the balance of the run.

Figure 4 also shows that considerable variation in the time-temperature relation can result from run to run. For run 1 the behavior of the minimum and maximum temperatures nearly parallel each other, that is, when one reverses trend, the other also reverses. On the other hand, run 3 is quite erratic; in some instances the trends of the minimum and maximum temperatures are in opposite directions. The erratic cooling can result in some rather large temperature differences on the bottom of the containers. Run 1 generally exhibited temperature differences of approximately  $100^{\circ}$  to  $200^{\circ}\text{F}$  during the greater portion of the test period. Run 2 shows a rather large temperature spread during the first 3 minutes of heating with temperature differences of approximately  $500^{\circ}\text{F}$  occurring in the time interval from 1 to  $1\frac{1}{2}$  minutes. After about  $3\frac{1}{2}$  minutes of operation the spread is reduced considerably and ranges from  $60^{\circ}$  to  $150^{\circ}\text{F}$  for the balance of the run. Run 3 exhibited temperature spreads of the order of  $600^{\circ}\text{F}$  during the first  $1\frac{1}{2}$  minute of operation; from  $1\frac{1}{2}$  to  $1\frac{1}{2}$  minutes the temperature spread was about  $80^{\circ}$  to  $150^{\circ}\text{F}$ . After  $1\frac{1}{2}$  minutes the temperatures became very erratic with temperature spreads ranging from nearly  $100^{\circ}$  to  $500^{\circ}\text{F}$  for the time interval from  $1\frac{1}{2}$  to 5 minutes.

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The unpredictable and erratic behavior of the temperatures on the bottom of the container, which can result in large temperature differences over distances of about 1 inch or less, would be undesirable in most cooling applications. In cooling systems where the maximum allowable temperature might be limited to a value of 2000° F, the erratic behavior of the coolant might lead to local hot regions that would be structurally undesirable. Furthermore, the large temperature gradients might induce thermal stresses that would lead to early structural failure.

The erratic behavior of lithium hydride as a coolant is not clearly understood. The bubbles of hydrogen gas that form within the molten lithium hydride as dissociation occurs may remain attached to the bottom portion of the container for significant lengths of time. The hydrogen gas within the bubble would provide a poor thermal conductor relative to lithium hydride. As a result, the temperature in the container wall would rise in the region surrounded by the bubble until such time that the hydrogen gas is dissipated and replaced by liquid lithium hydride and/or lithium.

Another possibility that may have contributed to the erratic behavior of the temperatures on the bottom of the container was the use of electrical resistance heating. Inasmuch as one of the products of the dissociation process is molten lithium, which is a good electrical conductor, the possible accumulation of lithium in local areas on the bottom of the container during dissociation could perhaps change the local electrical resistance and thus the local temperatures measured on the container bottom. Because the density of lithium is about 36 percent less than that of lithium hydride, and because of the active agitation of the fluid within the container during the dissociation process, it may be unlikely that significant quantities of lithium would accumulate on the bottom of the container. In any event, it is difficult to predict accurately what effect local collections of lithium on the bottom of the container might have on the temperature behavior and distribution. This difficulty is caused by many factors such as the size and stability of the local lithium deposit, the solubility of lithium in lithium hydride, the electrical contact between the lithium and the bottom of the container, the actual current paths in the system, and the thermal conductivities of the materials involved, which would all affect the local transient temperatures. In order to obtain some idea of whether the local temperature would be seriously affected by possible local deposits of lithium when the container bottom was electrically heated, several flame-heated containers charged with lithium hydride were investigated briefly.

The time-temperature patterns that resulted for the flame-heated container were compared with those of electrically heated containers for similar heat fluxes. The temperature patterns and the temperature differences were essentially the same for both heating methods. From this

evaluation it was felt that the effects of changes in local electrical resistances caused by possible local concentrations of lithium on the bottom of the container were not a significant influence on the local temperature and would not greatly affect the results reported herein.

Inasmuch as lithium hydride does not melt until it reaches a temperature of about  $1270^{\circ}\text{F}$ , the powder within the container might hinder considerably the heat-transfer process from the container wall to the lithium hydride until all the lithium hydride actually reached its melting temperature. If a relatively low-melting-point slurry could be produced by adding a low-melting-point material to the lithium hydride, the mobility and, therefore, the heat-transfer characteristics of such a slurry possibly would be superior to that of the lithium hydride powder alone. Any additive must, of course, be compatible with lithium hydride. Flakes of lithium (melting point of  $354^{\circ}\text{F}$ , ref. 3) were added to lithium hydride in two different amounts in order to provide a low-melting-point slurry. In one case a mixture of 13 grams of lithium hydride and 2 grams of lithium was tested, and in another, a mixture consisting of 11 grams of lithium hydride and 4 grams of lithium was used; the percentages of lithium by weight in these mixtures amounted to about 13 and 26 percent, respectively.

The results for charges containing 13 grams of lithium hydride and 2 grams of lithium are presented in figure 5. Figure 6 summarizes the results for charges containing 11 grams of lithium hydride and 4 grams of lithium. For comparison purposes, the time-temperature relations of an empty container and of a 15-gram lithium hydride charge (run 1, fig. 4(a)) are replotted in figures 5(a) and 6(a). Run 1 of the tests with the 15-gram lithium hydride charges was selected for comparison because, in general, it had the least temperature spread and could probably be considered the best of the three runs illustrated in figure 4.

The difficulty of the coolant being expelled from the container after about 5 minutes of heating also occurred for the runs with the lithium additive. As a consequence, the results in figures 5 and 6 for heating periods greater than 5 minutes are not significant.

A comparison of the results with the lithium additive (figs. 5 and 6) with those containing only lithium hydride (fig. 4) show no significant temperature differences during the first minute of heating (the time required for the lithium hydride to reach its melting temperature of  $1270^{\circ}\text{F}$ ). The similarity of all the results during the first minute of operation indicates that the addition of lithium did not improve the heat-transfer characteristics of the lithium hydride before it reached its melting point.

A comparison of the temperature patterns of figures 5 and 6 with those of figure 4 after 1 minute of operation indicates that a more uniform temperature on the container bottom results when lithium was added

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to the lithium hydride charge. Extremely erratic heating such as encountered in run 3 of the 15-gram lithium hydride charge (fig. 4(c)) was not encountered in any of the runs in which lithium was added to the initial charge. In general, the spread between the minimum and maximum temperatures was less than that with lithium hydride only. Also, the peak temperatures reached during the first 4 minutes of heating were less for the runs with the lithium additive. A comparison of the results of figure 5 with those of figure 6 does not show any marked differences; therefore, the charge with 4 grams of lithium does not seem to have any advantage over a charge with only 2 grams of lithium.

From these results it appears that the addition of lithium to form a low-melting-point slurry of lithium and lithium hydride does improve the cooling after the first minute of the heating cycle. The addition of lithium, however, decreases the amount of lithium hydride in a given charge and therefore potentially decreases the heat-absorbing ability of the charge by the dissociation process.

As mentioned previously, considerable difficulty was encountered with respect to retaining the coolant within the open-top container after about 5 minutes of heating. In an attempt to confine the coolant within the container and to prevent destruction of the insulation and ignition of combustibles, a vent system such as that mentioned in the APPARATUS was attached to two of the square-type containers. These containers were charged with 15 grams of lithium hydride powder, and two runs were made with constant electrical heat inputs of 2000 watts. The duration of heating for one run was 15 minutes; for the other run the heating time was terminated after 10 minutes because of a failure in the vent-tube attachment.

In general, the vented cover for the square-type container prevented ejection of the fluids from the container and thus prevented loss of dissociation potential and destruction of the insulation around the container and also eliminated combustion in the vicinity of the experiment.

The time-temperature results of the tests made with the vent system are shown by the crosshatching in figure 7 for both runs. The temperatures plotted are the minimum and maximum temperatures as indicated by the five thermocouples on the bottom of the container. Also shown in figure 7 by the dark areas are the temperature histories of two of the three open-top container runs made with 15 grams of lithium hydride and first discussed in figure 4. In figure 7(a) the dark area is from figure 4(a), which represents the best of the temperature patterns from figure 4; while in figure 7(b) the dark area is from figure 4(c), which is the most erratic temperature pattern from figure 4.

The results of the two runs for the vented-top containers indicated that considerably different temperature patterns can result from run to

run, much the same as was experienced when open-top containers with 15 grams of lithium hydride were tested. Run 1 (fig. 7(a)) exhibited a fairly uniform temperature increase with heating time, but run 2 (fig. 7(b)) exhibited an erratic temperature behavior for the time interval from  $1\frac{1}{2}$  to about 5 minutes. After 6 minutes of heating, both runs exhibited good cooling with relatively small differences between the minimum and maximum temperatures. After 10 minutes of heating, the mean temperatures for runs 1 and 2 were about  $1770^{\circ}$  and  $1800^{\circ}$  F, respectively. This trend indicated that, in spite of the erratic behavior of run 2 during the initial 5 minutes of heating, both runs achieved approximately the same temperatures after 10 minutes of operation. For run 2, after 15 minutes of heating, the minimum and maximum temperatures were  $2150^{\circ}$  and  $2270^{\circ}$  F, respectively; these compare to minimum and maximum temperatures of approximately the same values for an empty container (fig. 4(a)) after only  $2\frac{1}{4}$  minutes of heating. Effective cooling was therefore achieved in the vented-top containers for longer periods of time than in the open-top containers. This difference resulted, of course, from the fact that no coolant was ejected from the container with the vent system attached.

The erratic behavior of run 2 (fig. 7(b)) is not clearly understood, but may have been caused by the formation of hydrogen bubbles attached to the bottom surface of the container as discussed previously for the open-top containers. Another possibility for the erratic behavior of the vented-top container might be that when dissociation starts and agitation of the fluid within the container begins some remaining solids or relatively viscous fluids may enter and block the vent tube. Such blockage would result in an increased pressure within the container and cause the dissociation process to be retarded and therefore the container temperature to be increased. As the temperature increased within the container, the material causing the blockage in the vent tube would be melted, the blockage would be removed, and the pressure within the container would be reduced and an increased dissociation rate and a reduction in the container temperature would result.

#### CONCLUDING REMARKS

The results of investigating lithium hydride as a possible heat-sink material for use in the cooling of the structural components of hypersonic airplanes, space planes, reentry vehicles, and solid-propellant rocket engines indicate that effective use of its heat-sink potential is possible and that under the proper conditions lithium hydride can probably be used as a coolant provided that certain undesirable cooling characteristics can be tolerated. The results obtained herein were for a limited range of heat fluxes (10 to 40 Btu/(sec)(sq ft)) and relatively short periods

of operation (6 to 15 min). The problems that may be encountered from higher heat fluxes, long time operation, or repeated use of an actual system (such as corrosion, buildup of deposits on the container walls, clogging tendencies in the vent system, etc.) were not considered.

E-785 For a temperature of 1880° F, ground level pressure, and a maximum heat flux of 13 Btu per second per square foot, about 75 percent of the lithium hydride dissociated and its heat-sink capacity for these conditions was equivalent to about 6000 Btu per pound. The effects of higher temperatures or other heat fluxes are not known. It should be pointed out that lithium hydride has very good heat-sink capacity even without the additional benefits of dissociation; it may therefore be an attractive coolant or heat sink for certain applications where it would not be necessary for it to dissociate.

It appears that for the heat fluxes investigated (10 to 40 Btu/(sec)(sq ft)) and the type of experimental container employed, the cooling characteristics of lithium hydride during dissociation are such that erratic and unpredictable temperatures often resulting in large temperature gradients can occur in the container walls. Although dissociation can be expected to start at a temperature of about 1500° F for ambient ground level pressure, temperatures approaching 1900° F are required in order to dissociate more than about 75 percent of the material. The combination of erratic temperature behavior, high local temperatures, and large temperature gradients may make dissociating lithium hydride an unsatisfactory coolant from the structural design standpoint.

This investigation also indicated that relatively large ratios of the free surface area to volume of the liquid lithium hydride are required to obtain effective cooling. Lithium hydride does not appear to be a suitable coolant when confined to tubes having a diameter of 1/2 inch even for heat fluxes as low as 10 Btu per second per square foot. Successful use of dissociating lithium hydride in a practical cooling system will require considerable development.

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APPENDIX - CALCULATION OF HEAT ABSORBED BY DISSOCIATION OF  
LITHIUM HYDRIDE FROM ROOM TEMPERATURE TO 2000° F

The calculation to determine the theoretical heat content of lithium hydride for the temperature range from room temperature to 2000° F was the conventional type of heat calculation but slightly modified because of the uncertainties of the actual value of the heat absorbed by lithium hydride in the dissociation process. Inasmuch as the value for the amount of heat absorbed by lithium hydride during dissociation at a temperature of about 1517° F has not been established, the heat absorbed during dissociation was assumed equal to the heat of formation of lithium hydride. Because the heat of formation of lithium hydride is generally given for a standard temperature of 77° F (25° C), the calculation procedure employed herein was as follows:

(1) Assume that dissociation of the lithium hydride occurs at 77° F (25° C) and that the individual elements of lithium and hydrogen then remain to be heated to their respective final temperatures.

(2) Assume that the lithium was heated from 77° F to a final temperature of 2000° F.

(3) Assume that the hydrogen gas was heated from 77° to 1517° F and that at this temperature all the gas was vented from the system.

(4) Assume that no recombination of the lithium and hydrogen with each other occurs.

The heat of formation of lithium hydride was taken as -21.6 kilocalories per mole (ref. 1). The enthalpy values for lithium and hydrogen for the range of temperatures concerned herein were obtained from the tables of reference 3. A summary of the heat absorbed by the dissociation process and the heating of the lithium and hydrogen is as follows:

Heat absorbed by dissociation at 77° F, kcal/mole . . . . .	21.6 <sup>a</sup>
Heat absorbed by lithium between 77° and 2000° F, kcal/mole . . .	8.055
Heat absorbed by hydrogen between 77° and 1517° F, kcal/mole . .	2.835
Total . . . . .	32.490

<sup>a</sup>4890 Btu/lb.

This total heat absorbed converts to a value of 4.087 kilocalories per gram or 7355 Btu per pound.



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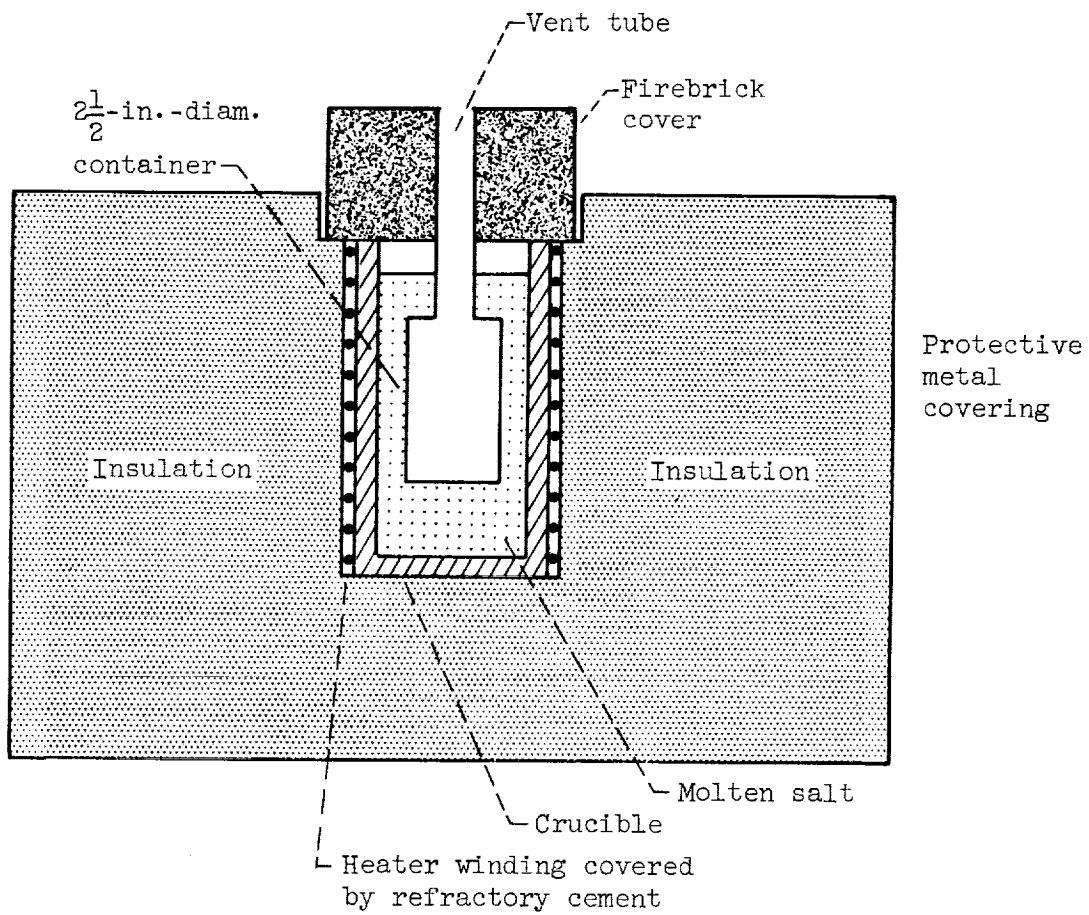
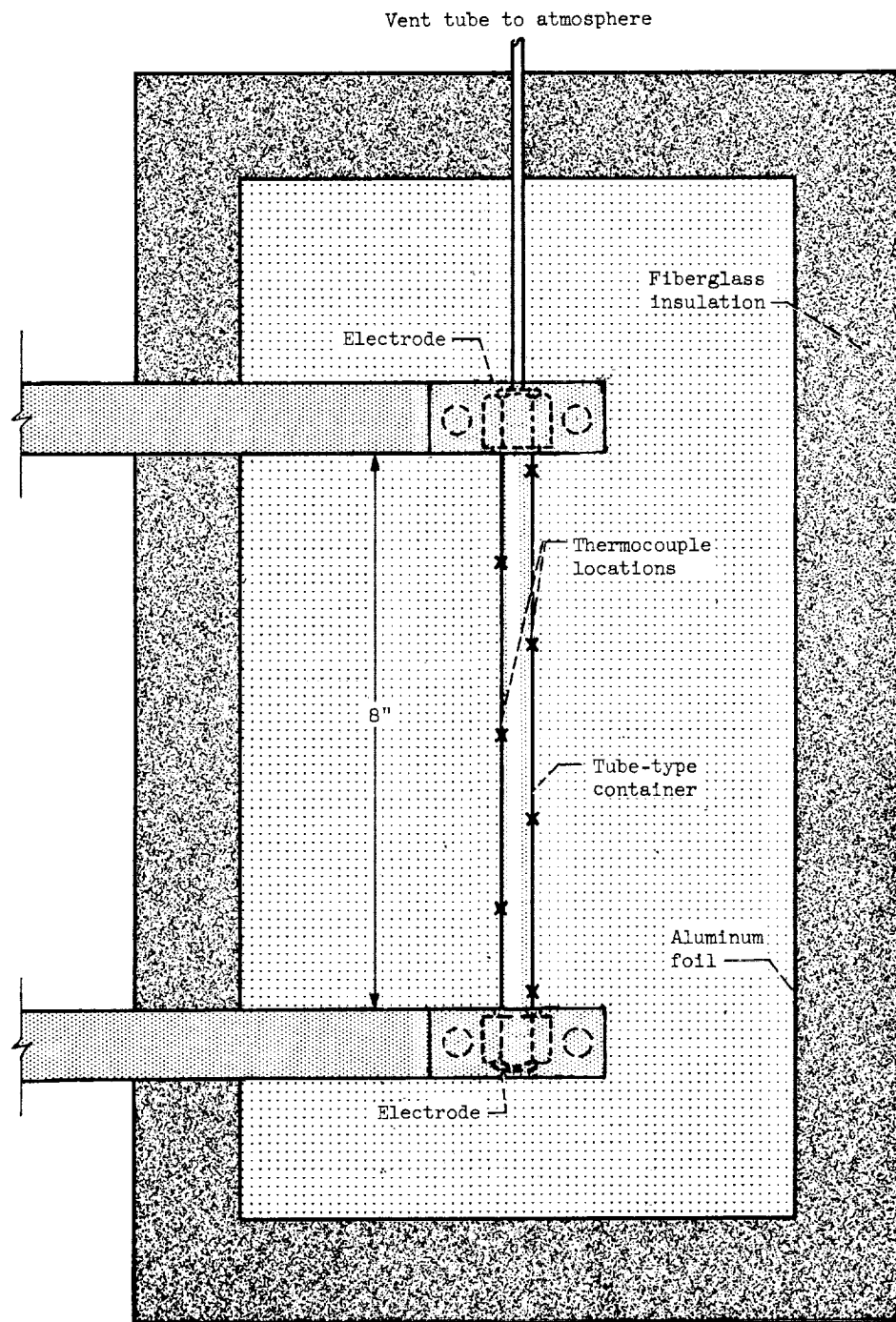
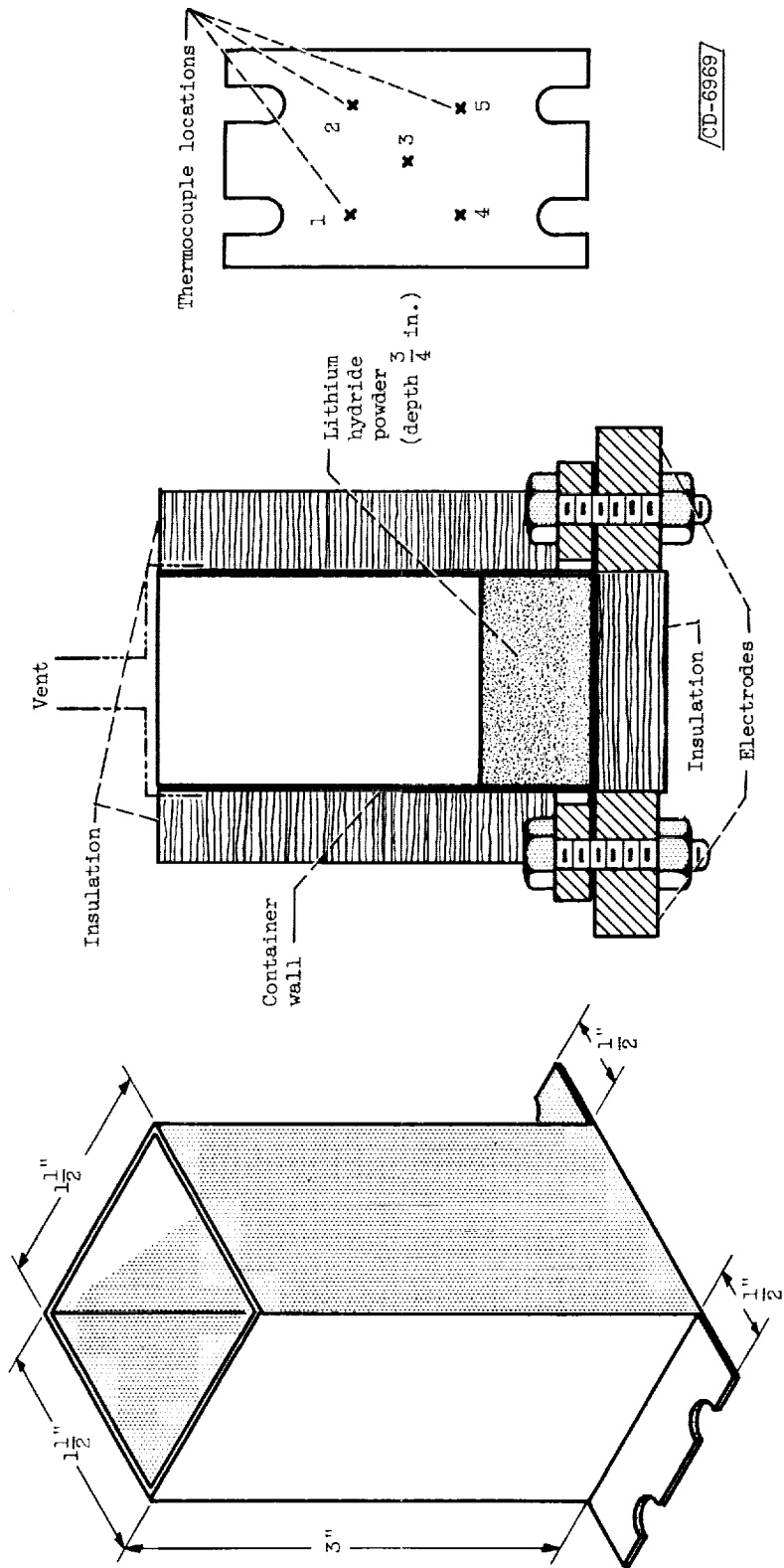


Figure 1. - Calorimeter-type apparatus for determining efficiency of lithium hydride cooling process.



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Figure 2. - Tube-type lithium hydride container installed in electrical resistance heating apparatus.

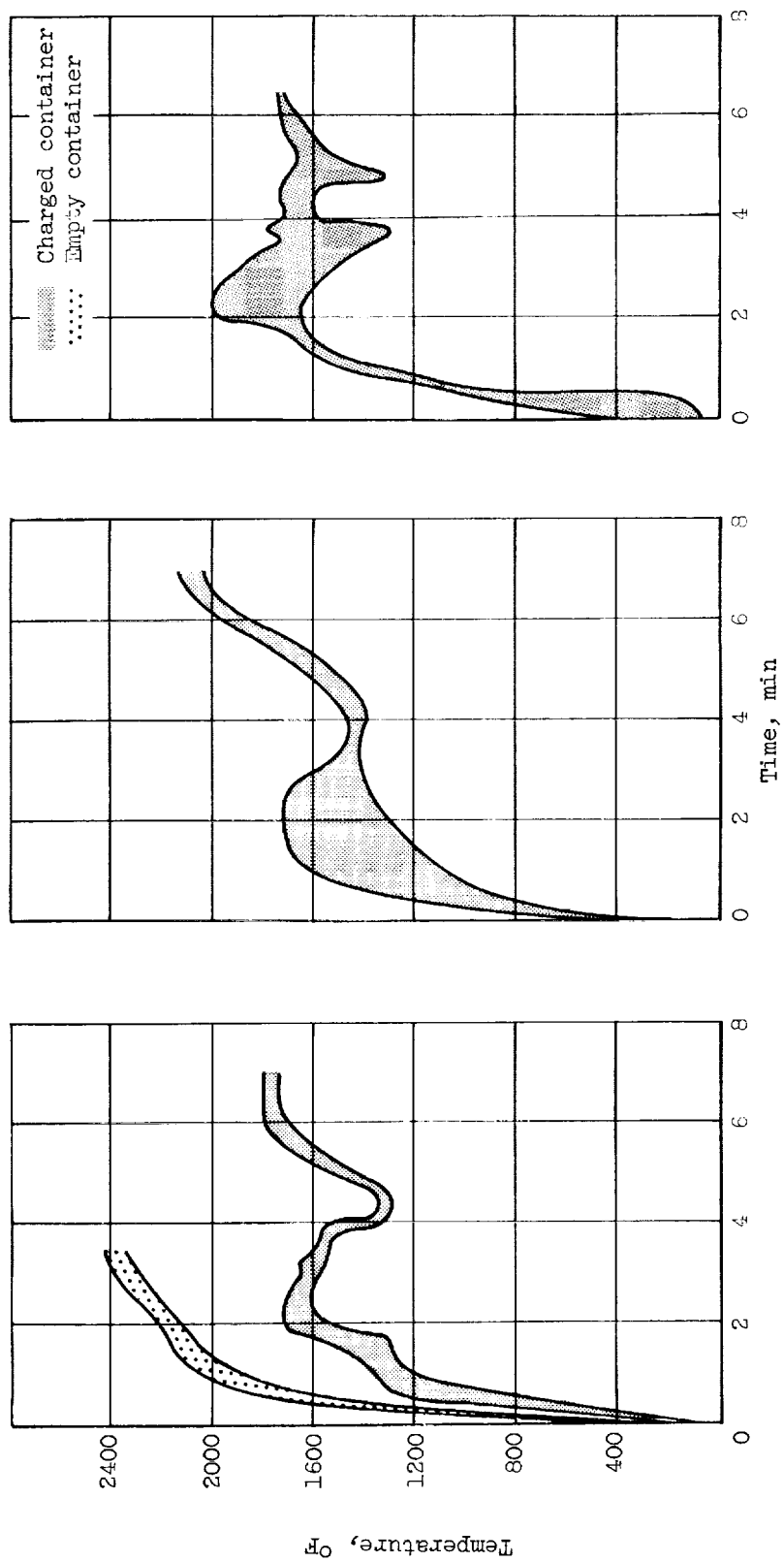


(a) Noninsulated container.

(b) Cross section of insulated container.

(c) Bottom view of container showing thermocouple locations.

Figure 3. - Square-type lithium hydride container.

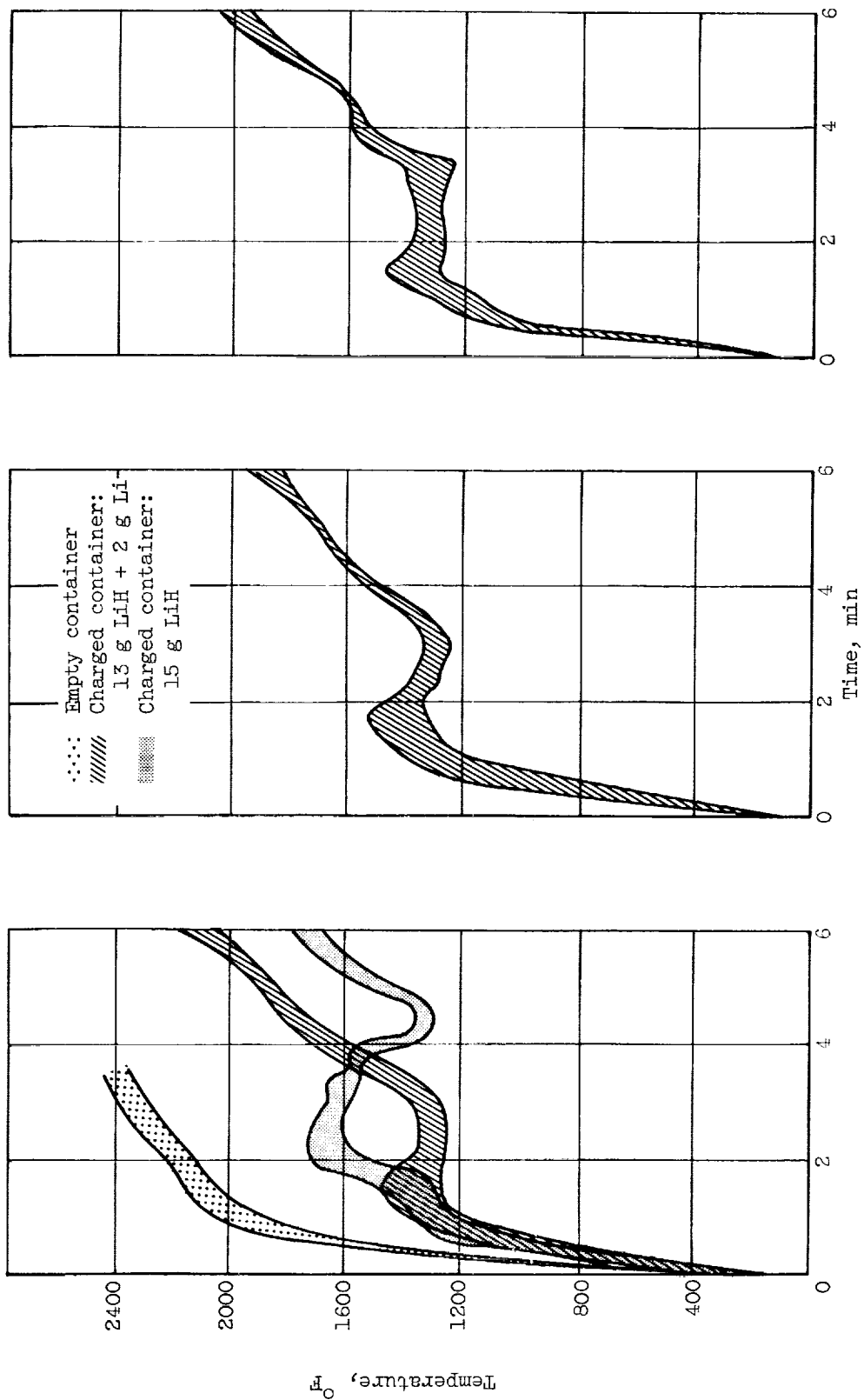


(a) Run 1.

(b) Run 2.

(c) Run 3.

Figure 4. - Temperature results of open-top container charged with 15 grams of lithium hydride powder.

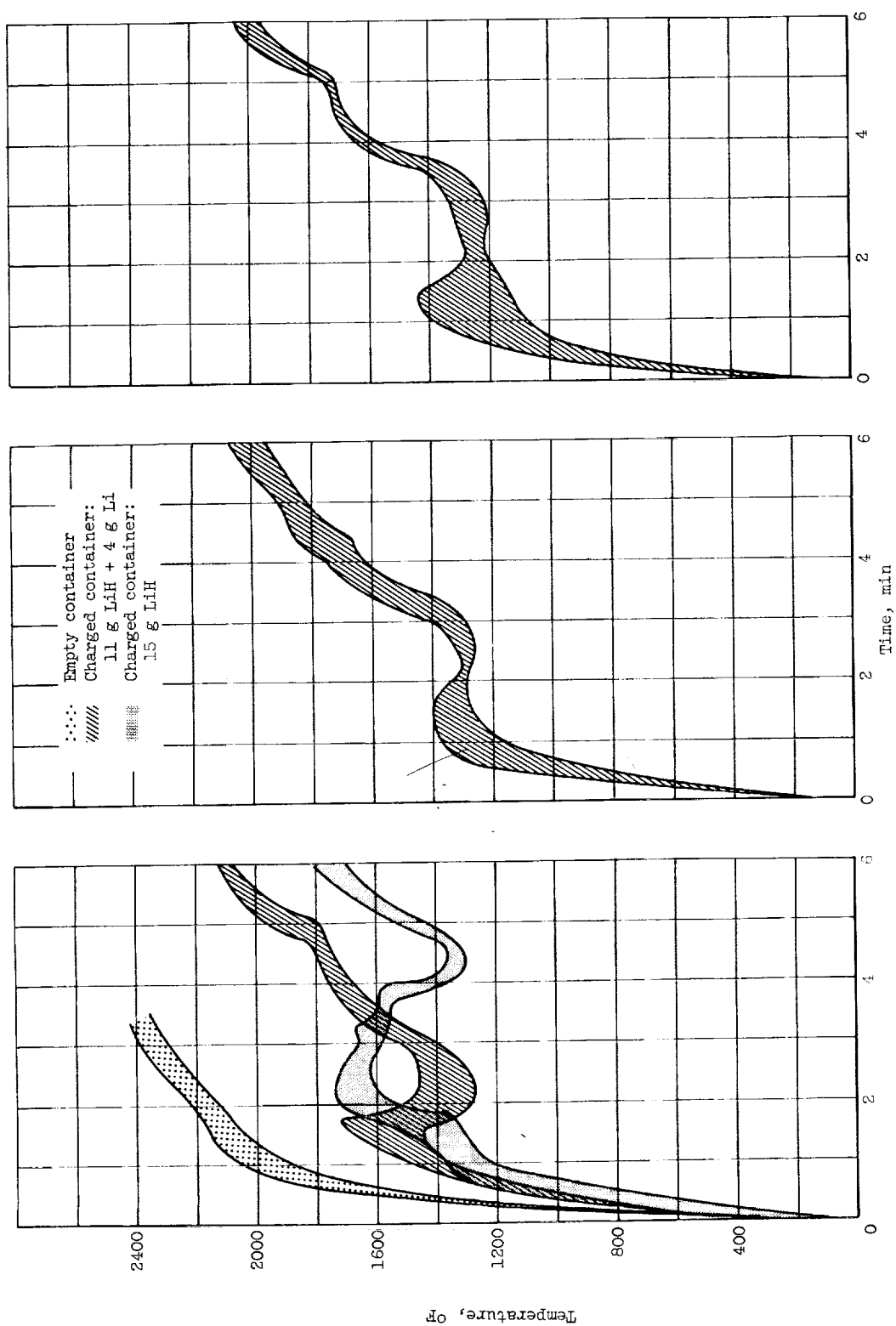


(a) Run 1.

(b) Run 2.

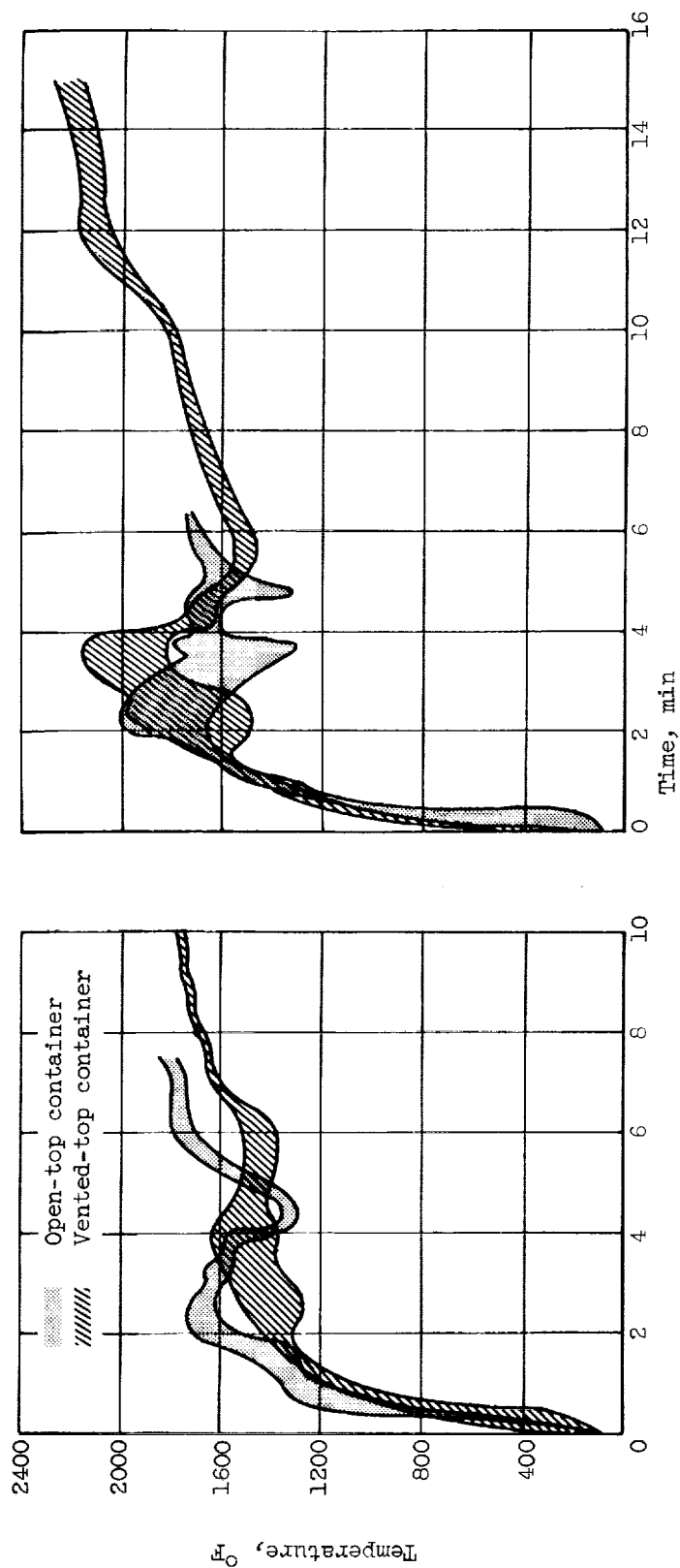
(c) Run 3.

Figure 5. - Temperature results of open-top container charged with 13 grams of lithium hydride plus 2 grams of lithium.



(a) Run 1.  
(b) Run 2.  
(c) Run 3.

Figure 6. - Temperature results of open-top container charged with 11 grams of lithium hydride plus 4 grams of lithium.



(a) Run 1.

(b) Run 2.

Figure 7. - Temperature results for vented-top container charged with 15 grams of lithium hydride.



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<p>NASA TN D-1198 National Aeronautics and Space Administration. EXPERIMENTAL INVESTIGATION OF LITHIUM HYDRIDE AS A HEAT-SINK MATERIAL. C. Robert Morse and Robert O. Hickel. May 1962. 22p. OTS price, \$0.75. (NASA TECHNICAL NOTE D-1198)</p> <p>In addition to determining the potential effectiveness of lithium hydride as a heat-sink material at a temperature of 1880° F, the cooling characteristics of dissociating lithium hydride were determined in containers charged with 15g of lithium hydride powder and electrically resistance heated to 2200° F. One type of container was 1-1/2 in. square and 3 in. high; the other type was a tube with a diameter of 1/2 in. and a length of 10 in. Wall temperatures of the containers were obtained as a function of heating time to evaluate the cooling performance. The heat fluxes for the experiments ranged from 10 to 40 Btu/(sec) (sq ft).</p> <p>Copies obtainable from NASA, Washington</p>	<p>I. Morse, C. Robert II. Hickel, Robert O. III. NASA TN D-1198  (Initial NASA distribution: 26, Materials, other; 52, Structures.)</p> <p>NASA</p>	<p>NASA TN D-1198 National Aeronautics and Space Administration. EXPERIMENTAL INVESTIGATION OF LITHIUM HYDRIDE AS A HEAT-SINK MATERIAL. C. Robert Morse and Robert O. Hickel. May 1962. 22p. OTS price, \$0.75. (NASA TECHNICAL NOTE D-1198)</p> <p>In addition to determining the potential effectiveness of lithium hydride as a heat-sink material at a temperature of 1880° F, the cooling characteristics of dissociating lithium hydride were determined in containers charged with 15g of lithium hydride powder and electrically resistance heated to 2200° F. One type of container was 1-1/2 in. square and 3 in. high; the other type was a tube with a diameter of 1/2 in. and a length of 10 in. Wall temperatures of the containers were obtained as a function of heating time to evaluate the cooling performance. The heat fluxes for the experiments ranged from 10 to 40 Btu/(sec) (sq ft).</p> <p>Copies obtainable from NASA, Washington</p> <p>I. Morse, C. Robert II. Hickel, Robert O. III. NASA TN D-1198  (Initial NASA distribution: 26, Materials, other; 52, Structures.)</p> <p>NASA</p>
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